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A SIMULATION STUDY OF WAREHOUSE LOADING AND UNLOADING SYSTEMS USING ARENA

(Kajian Simulasi ke atas Sistem Pemuatan dan Pemunggahan Gudang Menggunakan ARENA)

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ABSTRACT

In a warehouse, all the processes in the loading and unloading systems are run simultaneously. In this paper, animated ARENA simulation models for the loading and unloading systems in a warehouse are presented and discussed. The aim of the study is to find a strategy that will optimise the residence time of any lorry in the warehouse. The warehouses of interest are those that deal with already packed as well products that need sealing. The processes in the unloading system are checking, unloading, arranging and sealing, and storage of products; whereas for the loading system, the processes are processing the delivery order, picking and sealing, loading, and checking the load on the lorry. A simulation model of the existing system was developed and run to further understand the state of the operations. Utilisation of workers and waiting times at the various processes were discussed and analysed to identify the bottleneck in the system. It was identified that the interarrival time of customers' lorries; waiting time at the order picking, sealing and loading process; and the number of forklift are the contributing factors towards the performance of the loading system. The unloading system, which uses the company own lorry, has no bottleneck because the lorry is well scheduled. Four improvement models were developed and compared. It was found that, when other factors are relatively the same, by adding a forklift and a driver, the chosen model has not only overcome the overtime problem but also reduces the waiting time of the customers by almost two hours, i.e. by more than 65%.

Keywords: simulation; warehouse; loading; unloading; ARENA

ABSTRAK

Kesemua proses sistem pemuatan dan pemunggahan di sesebuah gudang adalah dijalankan secara serentak. Dalam makalah ini, dipersembah dan dibincangkan model simulasi ARENA yang beranimasi bagi sistem pemunggahan dan pemuatan di sebuah gudang. Tujuan kajian ini adalah mencari suatu strategi yang akan mengoptimumkan masa dalam kawasan bagi mana-mana lori di gudang tersebut. Tumpuannya adalah kepada gudang yang melibatkan produk yang siap terbungkus dan yang memerlukan perekatan. Proses-proses dalam sistem pemunggahan adalah proses memeriksa, memunggah, menyusun dan merekat, dan menyimpan produk; manakala bagi sistem pemuatan pula proses yang terlibat adalah mengeluarkan senarai tempahan, menyusun dan merekat, memuatkan produk, dan memeriksa muatan dalam lori. Suatu model simulasi sistem sedia ada telah dibangunkan dan dilarikan untuk lebih memahami keadaan operasinya. Hasil keputusan yang meliputi tahap penggunaan tenaga kerja dan masa menunggu dalam pelbagai proses dibincangkan dan dianalisis untuk mengenal pasti kesendatan dalam sistem. Dikenal pasti bahawa selang masa ketibaan lori pelanggan; proses penyusunan, perekatan dan pemuatan; dan bilangan trak angkat susun adalah faktor-faktor yang menyumbang kepada prestasi sistem pemuatan. Sistem pemunggahan tiada mengalami kesendatan kerana menggunakan lori syarikat itu sendiri dan terjadual dengan baik. Empat model simulasi penambahbaikan telah dibangunkan dan dibandingkan. Didapati bahawa, apabila faktor-faktor lain adalah terkawal, dengan menambahkan sebuah trak angkat susun dan pemandunya, sistem pilihan bukan sahaja berjaya menangani masalah kerja lebih masa yang dialami tetapi juga mengurangkan masa menunggu para pelanggan sebanyak hampir dua jam, iaitu lebih daripada 65%.

Kata kunci: simulasi; gudang; pemuatan; pemunggahan; ARENA

1. Introduction

Warehouse is an important distribution centre. Receiving and delivering are the interface of a warehouse for incoming and outgoing material flow. Incoming shipments are brought to the warehouse, unloaded at the receiving docks, and put into storage. Orders are picked from storage, prepared, and shipped to customers through docks by using van, lorry, truck and ship. The examples of receiving and delivering operations are the assignment of trucks to docks and the scheduling of loading and unloading activities (Gu *et al.* 2007).

In this work, the processes in the loading (delivering) and unloading systems (receiving) are carried out simultaneously daily at the warehouse. The processes in the unloading system are the arrival of supplier's lorry, checking, unloading, packing, sealing and storage. On the other hand, arrival of a customer's lorry, processing the delivery order, order picking, sealing, loading and checking are the processes undertaken in the loading system.

Nowadays, simulation studies are widely used for applications in engineering industry as a tool to increase the capacity of manufacturing and the profit of a company. Simulation studies are widely used in manufacturing, material handling, delivery, business processes, and transportation. Na *et al.* (2009) stated that simulation techniques are widely used in the analysis of port and terminal planning process and container handling system. Simulation studies has not only assisted in understanding the details of the processes, but the graphical modelling tools and animated run like those in ARENA also ease the involvement of the management in the development and the decision making processes (Seila *et al.* 2003).

In this paper, a simulation study was conducted in order to overcome some of the problems at a warehouse in a detergent factory, especially the waiting times at the various processes. The lorry drivers were found to have to queue for a long time to carry out the loading processes, where on average, they have to wait for about 182 minutes to be serviced, and an average residence time of 294 minutes (nearly 5 hours). These long waiting and total times mean the drivers will lose the opportunity to serve any other distributor and workers at the warehouse have to work overtime. The management realised that the problem is due to lack of facilities and workers. The facilities at the warehouse include forklift, sealing machine, dock, pallet and computer. Besides that, the management also aims to minimise the total expenditure at the factory. Hence, a simulation study was proposed to model the loading and unloading systems in order to find a strategy that will optimise the residence time of any lorry in the warehouse and overcome the overtime problem.

2. Related Works

Warehouse stores factory product or goods from suppliers and then distribute to wholesalers or customers. According to Van den Berg (1996), topics such as planning and controlling in warehouse management have been studied by researchers in both the arts and the sciences. Nevertheless, a good basic theory for design methodology of warehouse is still lacking.

In order to provide a characterisation of the warehouse, three different angles from which a warehouse may be viewed have to be considered: processes, resources, and organisation (Rouwenhorst *et al.* 2000). Products arriving at a warehouse will go through a number of steps called processes. Resources refer to all tools, equipment and personnel needed to operate a warehouse. Finally, organisation includes all aspects of planning and the control procedures used to run the warehouse system. A product is defined as a type of goods, for example shampoo of a certain brand in the study. An individual bottle is called an item and the combination of several items of several products requested by a customer is called a customer order.

Rockwell ARENA is a simulation and automation software from Rockwell Automation, Inc. It uses the SIMAN simulation language as the underlying building block and the current version is version 12.0 (ArenaSimulation 2009; ArenaWiki 2009). In ARENA, a simulation model can be built by putting together predefined modules, which represents processes or logic. Connector lines are used to connect modules and designate the flow of entities. Statistical data, such as cycle time and waiting time are recorded and displayed automatically as reports by ARENA.

ARENA has been widely used in simulating business processes and various kinds of discrete event operations. Large firms that use ARENA include GM, UPS, IBM, Nike, XEROX, Lufthansa, Ford, Lucent and Sony (ArenaSolution 2009). ARENA is used in Na *et al.* (2009) to model and simulate the terminal operation processes which involve ship arrival, loading, unloading and other related discrete events. Tahar and Hussain (2000) use ARENA to model and simulate the seaport operations at the Malaysian Kelang port. Deshpande *et al.* (2007) use ARENA to model and analyse truckload terminal operations in order to experiment with alternative dock assignment scenarios. Greasley (2008) gives a good account on the usage of simulation modelling in the manufacturing sector, and stresses that most are for the analysis of production planning and for control purposes. Greasley uses ARENA simulation to investigate the effect of conveyor breakdowns on the performance of a continuous operations process. ARENA has also been used to simulate the congestions of visitors at the Shanghai Expo by Jin (2009).

In relation to simulation of loading and unloading systems, Na *et al.* (2009) use ARENA to model and simulate the terminal operation processes which involve ship arrival, loading, unloading and other related discrete events. The paper also gives an overview of the methodology in using ARENA to model the system and explains that ARENA provides extendable simulation environments through graphical and animation modelling facilities. The simulation model developed is calibrated and verified with actual operation records from 15 different container terminals.

Tahar and Hussain (2000) use ARENA to model and simulate the seaport operations at the Malaysian Kelang port in the context of commercial activities. The main aim of the work is improving the logistics processes at the port. The simulation model had been carried out using the ARENA package because of “its flexibility in modelling many scheduling and planning problems and its user-friendly modelling environment”. Fitting of interarrival times of ships was done using the ARENA input tool which fits probability distributions to the real data collected. The models also involve the assignments of berth, crane and prime movers in the port operation.

In this study, the main aim is to model and analyse the loading and unloading systems at a warehouse. The simulation experiments were used to evaluate the alternative strategies in order to optimise the waiting times and residence times of any lorry in the warehouse, as well as minimising the operational cost involved.

3. Methodology

The framework of this research is made by referring to simulation studies of Law and Kelton (1991), Bank *et al.* (1996), Barnes *et al.* (1997) and the literature mentioned in Section 2. The framework of this study is as shown in Table 1. The framework has five major phases, namely pre-assessment, research, simulation model development, discussion and decision analysis as well as conclusion and recommendation.

The purpose of pre-assessment is to identify the statement of the problems. This is the first step in doing research. This study is conducted at the warehouse of a detergent factory. The focus is on the loading and unloading systems. The processes within the two systems are best described by Figures 1 and 2.

Table 1: The research framework

Main phases	Steps
Pre-assessment	Problem formulation and plan study
Research	Data collection and model definition Validation?
Development of simulation model	Built up computer programme and defined model Do the pilot run Validation? Experimental design Do the production run
Discussion and analysis of results	Analysis data output
Conclusion and recommendation	Suggestion, documentation and implementation of model

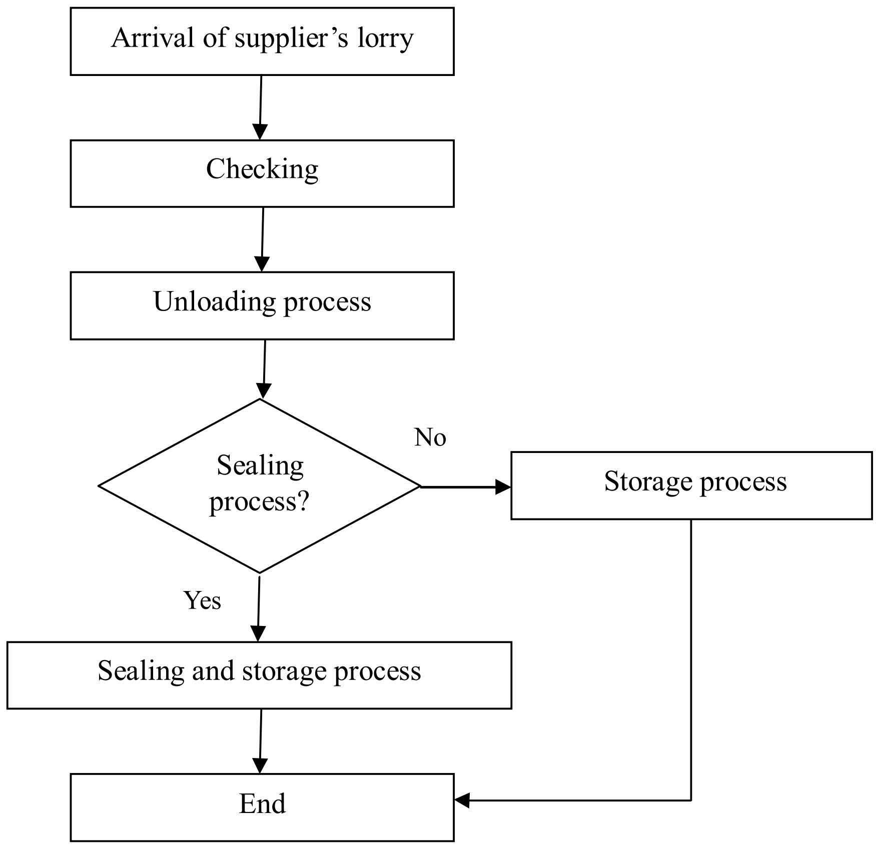


Figure 1: Flowchart for the processes of the unloading system

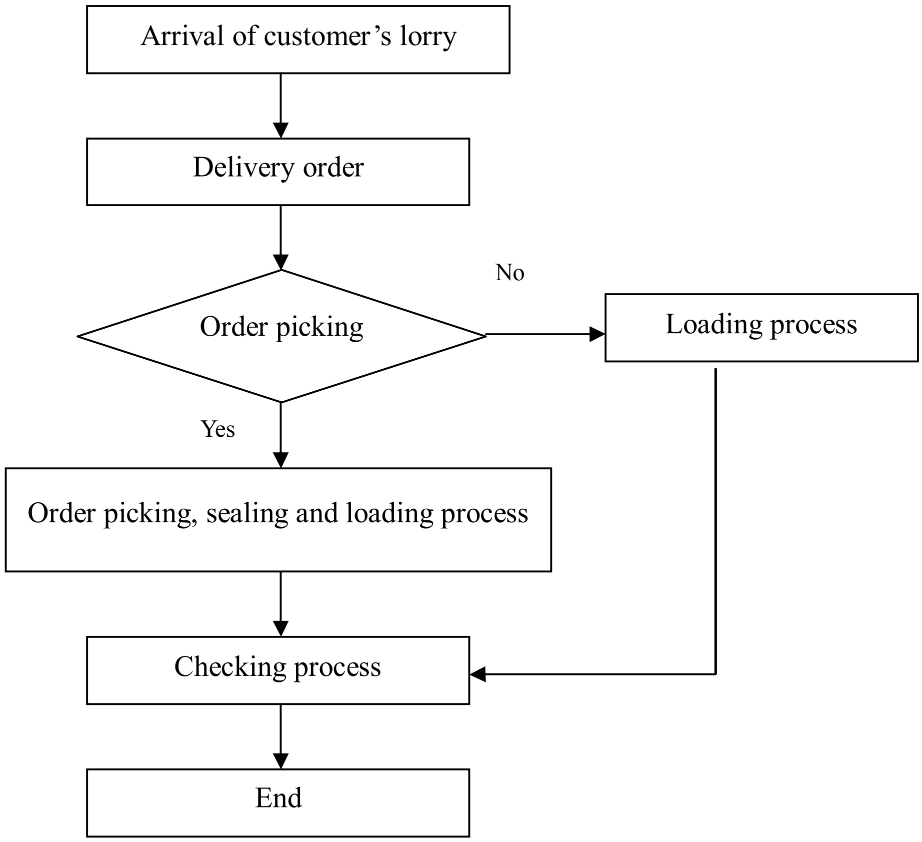


Figure 2: Flowchart for the processes of the loading system

Field research is conducted directly at the warehouse. This will ensure that the latest data, information and explanation of statement of problems in this study are verified. Field research also enables the researchers to understand and see the actual operations and to come up with the best design possible. Real data for every operation at the warehouse was collected in real time over a six days period at the warehouse. Interview with the supervisor and workers of the warehouse has also been conducted in order to obtain more information and understanding of the loading and unloading systems. Besides that, observations on the infrastructures such as racks, pallets, goods, forklifts, and computers have also been recorded for future considerations.

Input analyser is a standard component in the ARENA environment. This effective and versatile component is used to determine the probability distributions of the interarrival times and the times of the various services of the operations in the loading and unloading systems.

In this study, six original simulation models for Monday to Saturday were developed in order to experiment with and to analyse the operations for each of the days of the week. It was found that the model for Tuesday had the highest number of customers' and supplier's lorries and the longest waiting times. Therefore, this model was chosen for further analysis because if the operations on Tuesday can be improved to a satisfactory level, all the other days will definitely could be improved to an even better state.

The simulation systems were developed using the create, process, decide and dispose modules of ARENA. Besides that, representative and accurate data must be entered into the right modules within the flowchart window to model the various servicing and waiting times. The original simulation model of the loading and unloading systems at the warehouse is given in Figure 4. Queue animation has been incorporated and is an important element of the model in order to highlight to the management the number of lorries waiting at the various processes.

According to Kelton *et al*. (2007), higher number of replications of the system run will lead to more precise results for the simulation model and hence is preferred in practice. However, as the system is developed using the student version of ARENA, only 10 replications have been used. Replication period is defined as the period to solve all the processes in the loading and unloading systems. For the original simulation model, the replication period is 14 hours since the workers worked from 8 a.m. to 10 p.m. on Tuesday. Figure 6 shows an example of the results for the model in the SIMAN format.

Other important steps in the system development are the verification and validation of the model (Kelton *et al.* 2007). Verification is defined as the task of ensuring that the designed models function according to the intended design (model), while validation is the task of ensuring that the developed models function as in the actual system. Anderson *et al.* (2005) state that the commonly used validity tolerance is 10%. The tolerance level means that the obtained simulation output should not deviate more than 10% of the real output. The formula to test the model validity level in percent of error is given as:

$$Percentage\ of\ error = \frac{|\,output(simulation) - output(data)\,|}{output(data)} \times 100\%$$

where *output* (*simulation*) refers to the number of entities processed by the simulation model, and the *output* (*data*) is the number of entities observed in the real system.

4. Results and Discussion

The distributions of the waiting and service times for the processes in the loading and unloading systems were fitted using the input analyser tool based on the data for Tuesday. The distributions and the parameters are given in Table 2.

Table 2: Distribution of the processes for Tuesday

Name	Distribution	Expression
Interarrival time of customer's lorry	Beta	-0.5 + 76 * BETA(0.461, 1.05)
Delivery Order	Beta	2.5 + 3 * BETA(1.03, 1.44)
Order picking, sealing and loading	Triangular	TRIA(28, 46.2, 210)
Loading	Exponential	35 + EXPO(54.4)
Checking	Triangular	TRIA (1.5, 3.75, 4.5)
Interarrival time of supplier's lorry	Poisson	POIS(35.3)
Unloading	Beta	5.5 + 3 * BETA(0.842, 1.4)
Sealing and storage	Beta	21.5 + 4 * BETA(1.66, 1.53)
Storage	Triangular	TRIA (7.5, 12, 14.5)

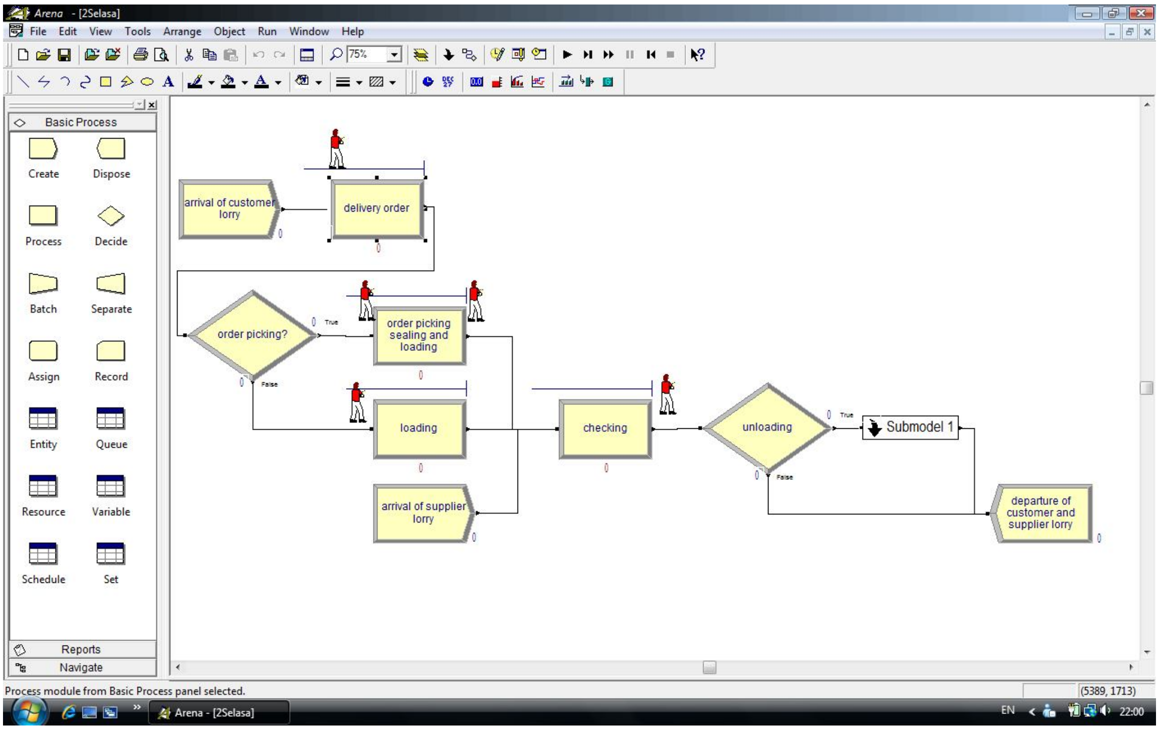


Figure 4: Original simulation model of the loading and unloading systems

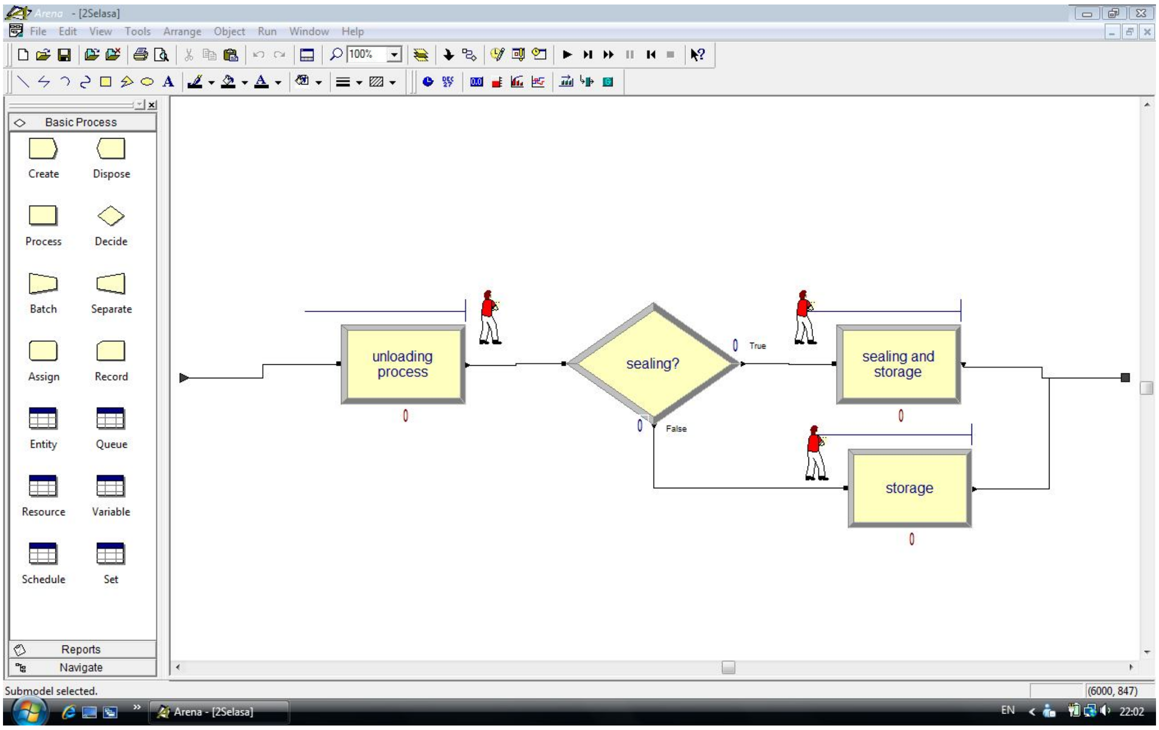
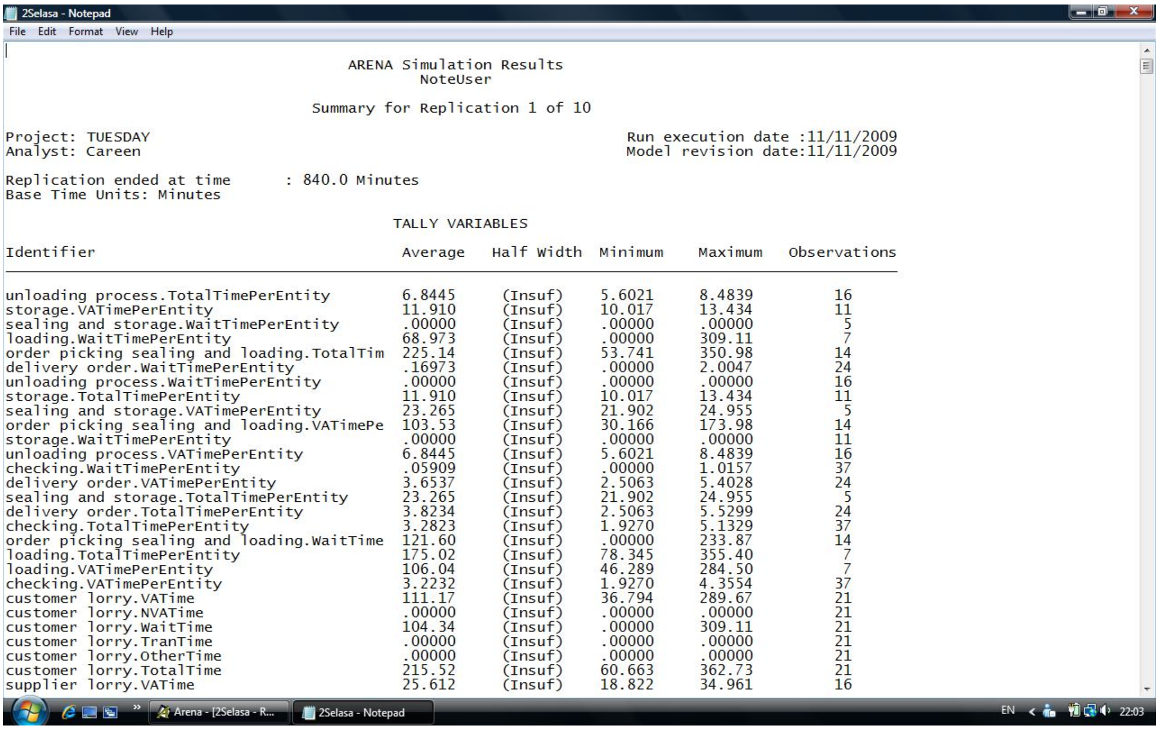


Figure 5: Submodel of the original simulation model



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                         ARENA Simulation Results
                                NoteUser

                     Summary for Replication 1 of 10

Project: TUESDAY                                   Run execution date :11/11/2009
Analyst: Careen                                    Model revision date:11/11/2009

Replication ended at time      : 840.0 Minutes
Base Time Units: Minutes

                              TALLY VARIABLES

Identifier                            Average    Half Width  Minimum    Maximum   Observations
______________________________________________________________________________________________

unloading process.TotalTimePerEntity   6.8445     (Insuf)    5.6021     8.4839        16
storage.VATimePerEntity                11.910     (Insuf)    10.017     13.434        11
sealing and storage.WaitTimePerEntity  .00000     (Insuf)    .00000     .00000         5
loading.WaitTimePerEntity              68.973     (Insuf)    .00000     309.11         7
order picking sealing and loading.TotalTim 225.14 (Insuf)    53.741     350.98        14
delivery order.WaitTimePerEntity       .16973     (Insuf)    .00000     2.0047        24
unloading process.WaitTimePerEntity    .00000     (Insuf)    .00000     .00000        16
storage.TotalTimePerEntity             11.910     (Insuf)    10.017     13.434        11
sealing and storage.VATimePerEntity    23.265     (Insuf)    21.902     24.955         5
order picking sealing and loading.VATimePe 103.53 (Insuf)    30.166     173.98        14
storage.WaitTimePerEntity              .00000     (Insuf)    .00000     .00000        11
unloading process.VATimePerEntity      6.8445     (Insuf)    5.6021     8.4839        16
checking.WaitTimePerEntity             .05909     (Insuf)    .00000     1.0157        37
delivery order.VATimePerEntity         3.6537     (Insuf)    2.5063     5.4028        24
sealing and storage.TotalTimePerEntity 23.265     (Insuf)    21.902     24.955         5
delivery order.TotalTimePerEntity      3.8234     (Insuf)    2.5063     5.5299        24
checking.TotalTimePerEntity            3.2823     (Insuf)    1.9270     5.1329        37
order picking sealing and loading.WaitTime 121.60 (Insuf)    .00000     233.87        14
loading.TotalTimePerEntity             175.02     (Insuf)    78.345     355.40         7
loading.VATimePerEntity                106.04     (Insuf)    46.289     284.50         7
checking.VATimePerEntity               3.2232     (Insuf)    1.9270     4.3554        37
customer lorry.VATime                  111.17     (Insuf)    36.794     289.67        21
customer lorry.NVATime                 .00000     (Insuf)    .00000     .00000        21
customer lorry.WaitTime                104.34     (Insuf)    .00000     309.11        21
customer lorry.TranTime                .00000     (Insuf)    .00000     .00000        21
customer lorry.OtherTime               .00000     (Insuf)    .00000     .00000        21
customer lorry.TotalTime               215.52     (Insuf)    60.663     362.73        21
supplier lorry.VATime                  25.612     (Insuf)    18.822     34.961        16
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Figure 6: A sample of the Arena simulation results for the original model

The results of original simulation model for Tuesday were collected in the format of SIMAN report. The unit of time is in minute and the results are shown in Tables 3 and 4.

Table 3 shows that the average waiting time, average service time, average overall residence time, and number of lorries in and out of the loading and unloading systems at the warehouse on Tuesday. Average waiting time, service time and total time for arrival of the supplier's lorry were excluded from the analysis because in the real system, the supplier's lorry for transporting goods between the warehouse and the manufacturing plant is well scheduled. No waiting time is involved.

The average waiting times for arrival of customer's lorry; order picking, sealing and loading (OPSL) process, as well as the loading process were high, namely 181.93 minutes, 187.88 minutes and 159.03 minutes. Customer's lorry drivers waited for a long period of time due to the slow and congested service process. Furthermore, OPSL process in the loading system is rather complicated and take longer time to complete compared to the one during unloading. By referring to Table 3, the average service times of the processes are also high. This long service time could most probably be caused by lack of staff and forklift.

For the simulation period, it was found that there were 24 customers' lorries which entered the warehouse but only 20 had left. In other words, the simulation period is insufficient to serve all the lorries. The problem is traceable, and a check on the OPSL process shows that 19 lorries had entered the process but only 15 were completed.

For all the processes involved in the unloading system, the average waiting times are generally 0 and the average service times are short. These show that the unloading system is operating systematically and in satisfactory level. These also tally well with the fact that the warehouse actually uses the company's own lorry for transporting goods between the warehouse and the manufacturing plant, where the trips are well scheduled. From the table, the numbers of supplier's lorries which arrived are equal to numbers of lorries that had departed. In other words, all the supplier's lorries managed to go through all the processes in the unloading system in fixed duration.

Table 3: Results of the original simulation model for Tuesday

Entity/Process	Average waiting time	Average service time	Average total time	Number of lorry In	Out
Customer's lorry	181.93	112.09	294.02	24	20
Delivery Order	1.1319	3.7754	4.9073	24	24
Order picking, sealing and loading	187.88	101.31	289.19	19	15
Loading	159.03	116.55	275.58	5	5
Checking	0.07205	3.1553	3.2274	36	36
Supplier's lorry	0.1693	26.605	26.622	16	16
Unloading	0	6.7559	6.7559	16	16
Sealing and storage	0	23.959	23.959	7	7
Storage	0	11.227	11.227	9	9

In short, bottlenecks were found only in the loading system. The processes of loading and OPSL had been shown to be the cause for the long average waiting times.

Table 4 presents the average value of man power utilisation for all the workers in the loading and unloading systems on Tuesday. The average value of utilisation is a value between 0 and 1, where 1 means that the worker is fully occupied all the time, while a 0 means the worker is idle.

Table 4: Average value of utilisation of the workers

Worker	Average value of utilisation
Loading driver 1.1	0.93306
Loading driver 1.2	0.96539
Loading driver 2	0.69376
Unloading driver 1	0.12868
Unloading driver 2	0.19969
Unloading driver 3	0.12029
Clerk	0.10787
Checker	0.13532

In the loading system, there were 2 drivers who were involved with the OPSL process, namely loading driver 1.1 and loading driver 1.2. From the table, it is clear that the average values of utilisation of both of these drivers were high, which are 0.93306 and 0.96539 respectively. This means that both drivers were busy working almost all the time. The utilisation of the loading driver 2 in the loading process is 0.69376. In fact, in the actual operation at the warehouse, loading driver 2 will help loading driver 1.1 and 1.2 whenever he is available but they had been working until midnight.

Based on the observed problems in the original simulation model, several recommendations have been proposed for a better system. The factors to be considered are:

i. Arrival time of customers' lorries
   In order to reduce the waiting time of a customer, the arrival time of customers' lorries should be scheduled first. Warehouse management can schedule arrival time for each lorry. We recommend that the interarrival time of customers' lorries should be set to 20 or 30 minutes.

ii. Number of workers
   Additional worker is needed in the OPSL process since the average value of man power utilisation of the loading drivers is very high. The suggestion is to employ an additional worker and to acquire one more forklift. The worker uses a forklift to transport the pallets during the loading process.

iii. Service process time
   The maximum and minimum times in the OPSL process in the real system on Tuesday were 28 minutes and 210 minutes respectively. The average time was 88 minutes. These data was model as TRIA(28, 46.2, 210) by the input analyser where 28 and 210 are the minimum and maximum times, while 46.2 is the mode of the triangular distribution. The times may be modified to have a smaller variation with more workers employed.

Four improvement models (IMs) have been investigated based on the factors discussed. The parameters of the IMs are as given in Table 5. The service time has been set using the distribution found but with the mode set to the average time. Average time has been used as the mode to stress that the workers do not have to hurry most of the time and the system can still cope well if other factors are improved. The total numbers of lorries for the loading and unloading systems have been maintained in models IM1, IM2 and IM3. Model IM4 was used to see how the system copes if the number of lorries are not limited.

Table 5: Parameters of the four different improvement models

Item	IM1	IM2	IM3	IM4
Interarrival time of customer's lorry (minute)	20	20	20	20
Additional worker	1	1	0	1
Service time	TRIA(28, 88, 210)	TRIA(28, 88, 210)	TRIA(28, 88, 210)	TRIA(28, 88, 210)
Replication period (hour)	14	12	12	12
Total number of lorries	40	40	40	Unlimited

Model IM1 is the first model proposed which aims to evaluate the effect of scheduling the arrival of customers' lorries and getting an additional worker and a forklift to help with the OPSL and the loading processes. The replication period was set to 14 hours, i.e. the observed current working hours. Model IM2 is just another instance of model IM1 where the replication period was changed to 12 hours, i.e. to analyse how the new scheme copes with the processes under normal working hours of the warehouse. It was found that both models have improved the waiting times significantly (Table 6). Then model IM3 was proposed to see how the proposed system copes without the additional worker. Model IM4 was used to see the effect on the system if unlimited number lorries were to be allowed into the system. The results of the IMs are given in Table 6.

Table 6: Results of the four improvement models for the loading system

Improvement Model	Entity/Process	Average waiting time	Average service time	Average total time	Number of lorry In	Out
IM1	Customer's lorry	66.720	112.43	179.15	24	24
	Delivery Order	0	3.5549	3.5549	24	24
	Order picking, sealing and loading	61.571	101.34	162.91	18	18
	Loading	81.036	118.07	199.10	6	6
IM2	Customer's lorry	62.051	109.94	171.99	24	23
	Delivery Order	0	3.5549	3.5549	24	24
	Order picking, sealing and loading	54.952	97.725	152.67	18	17
	Loading	81.038	118.07	199.10	6	6
IM3	Customer's lorry	69.380	97.492	166.87	24	19
	Delivery Order	0	3.7946	3.7946	24	24
	Order picking, sealing and loading	100.16	99.733	199.89	17	12
	Loading	54.228	71.984	126.21	7	7
IM4	Customer's lorry	51.130	112.43	179.15	37	21
	Delivery Order	0	3.7754	4.9073	37	36
	Order picking, sealing and loading	38.758	110.34	149.10	28	15
	Loading	81.036	118.07	199.10	8	6

The simulation results show that model IM2, where an additional driver is employed to help with the OPSL process, has produced the best results. The customer waiting time has been reduced from 181.93 minutes on average, to 62.051 minutes, i.e. cut down by more than 65%. The management has to purchase a forklift for the driver. The waiting time in the OPSL process has been reduced to 54.952 minutes, and it does not bring any negative impact to the other processes. A total of 23 customers' and 16 supplier's lorries are served within the simulated 12 working hours. Employment of an additional driver and the purchase of a forklift may have incurred a direct additional cost, but this should give higher satisfactions to both the workers and the customers which are good for the company. Besides that, overcoming the overtime problem has also saved some cost.

5. Conclusions

In this study, simulation and modelling of the loading and the unloading systems in a warehouse that involves ready packed as well as products that need sealing has been conducted using ARENA. As expected, the unloading system involving the use of the company's own lorry which is well scheduled, is functioning satisfactorily. On the other hand, the loading system has been identified to have the long waiting times for the OPSL and the loading processes. Therefore four improvement models have been experimented with in order to find a strategy that will optimise the residence time of any customer's lorry without affecting the other processes. Out the four models, model IM2 where the arrival of lorries is scheduled and an additional forklift and a driver have been used, has produced the best results. It has not only overcome the overtime problem but also reduces the waiting time of the customers by almost two hours, i.e. by more than 65%, and reduces the waiting time in the OPSL process by more than 70%. Furthermore, the fact that the simulation is done for a twelve-hour period also means that overtime is not needed. However, since this work does not consider cost and profit, it is worth considering this issue in further investigation.

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